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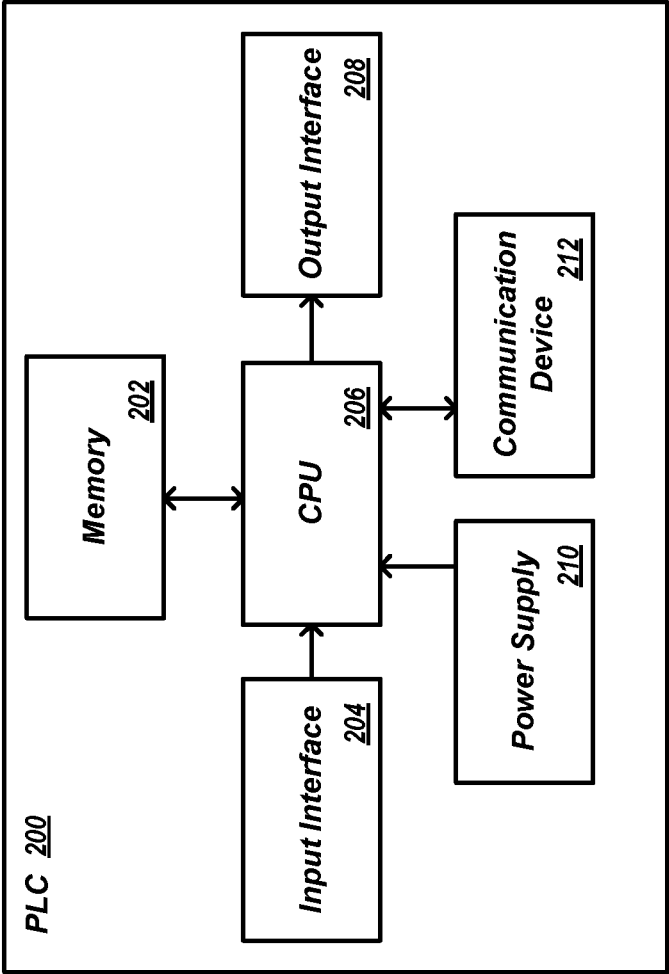


FIG. 2

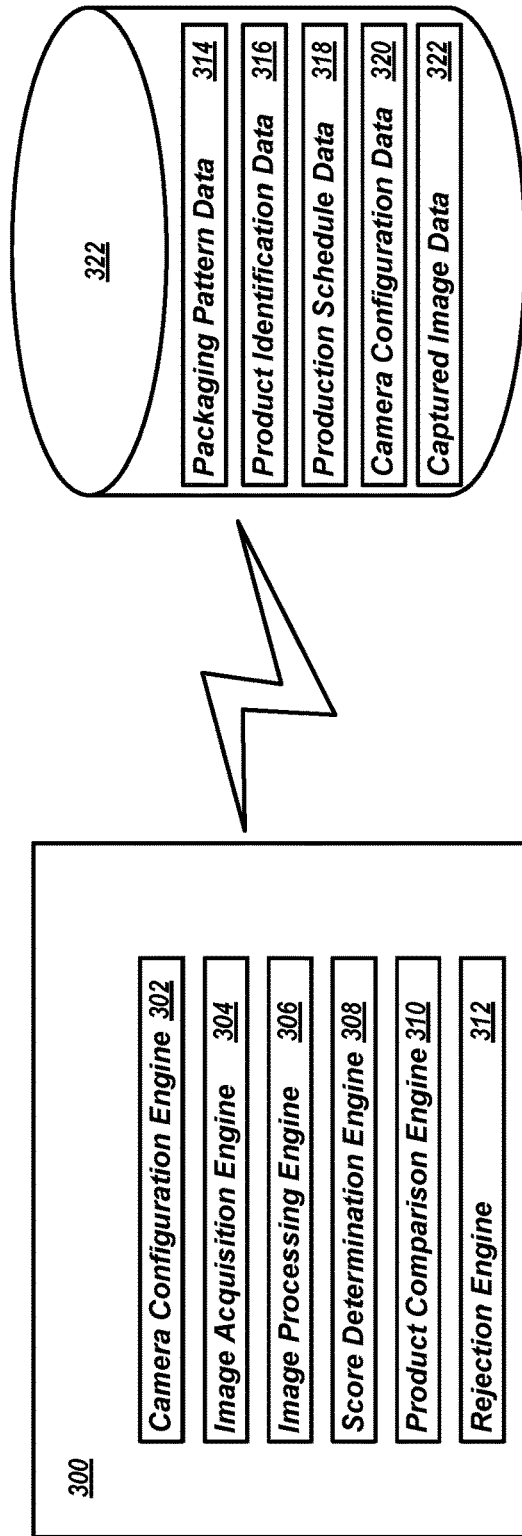


FIG. 3

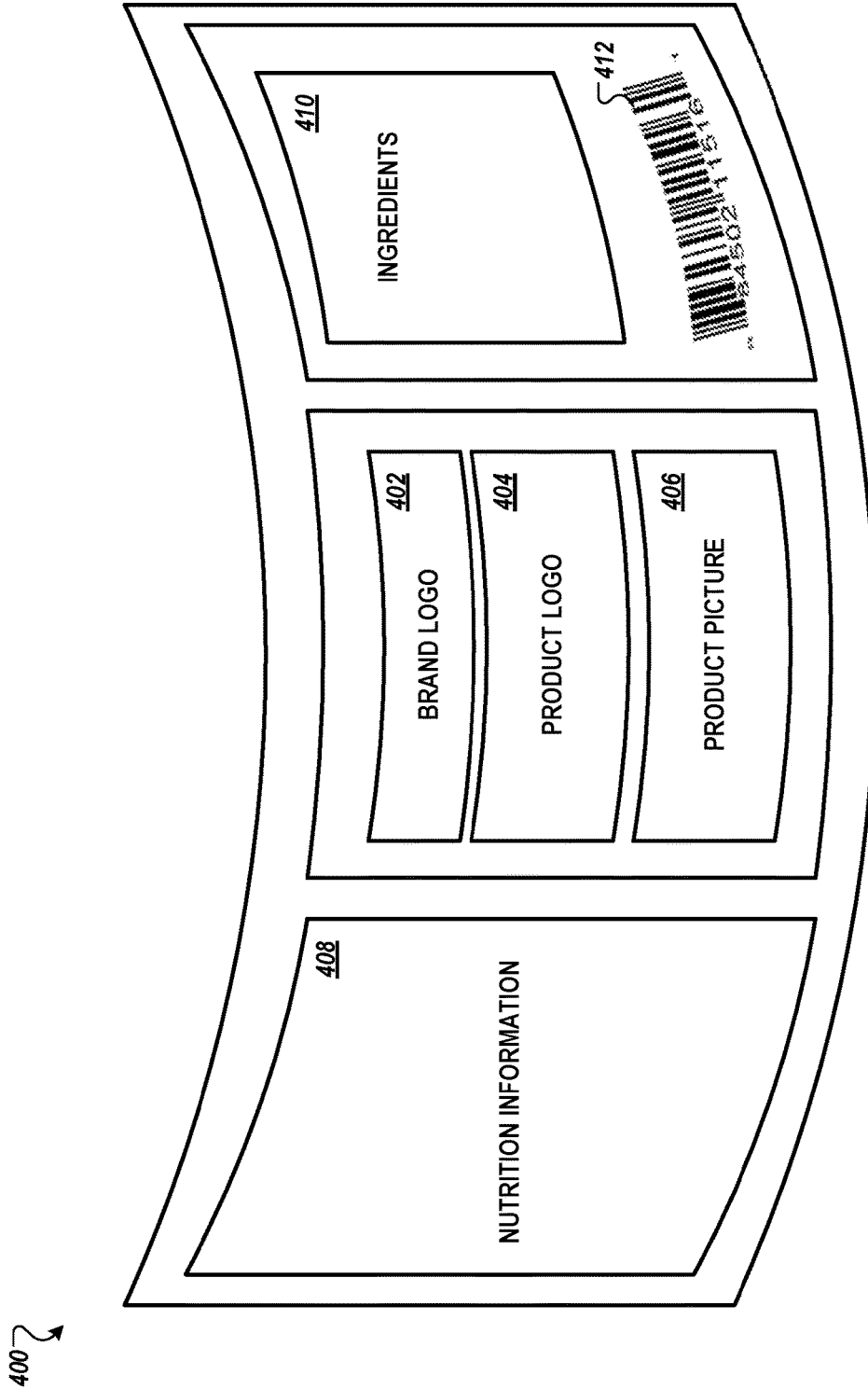


FIG. 4

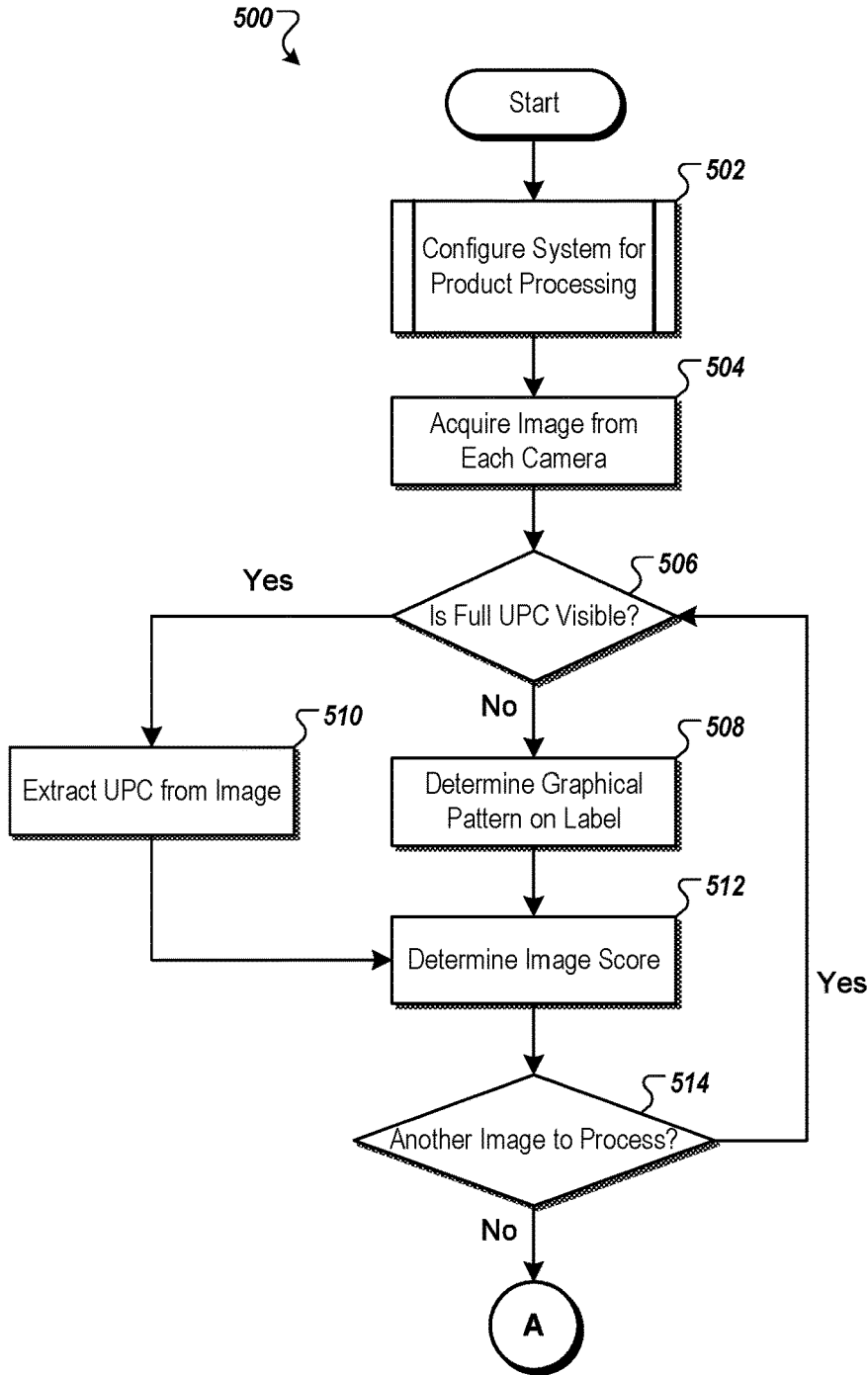


FIG. 5A

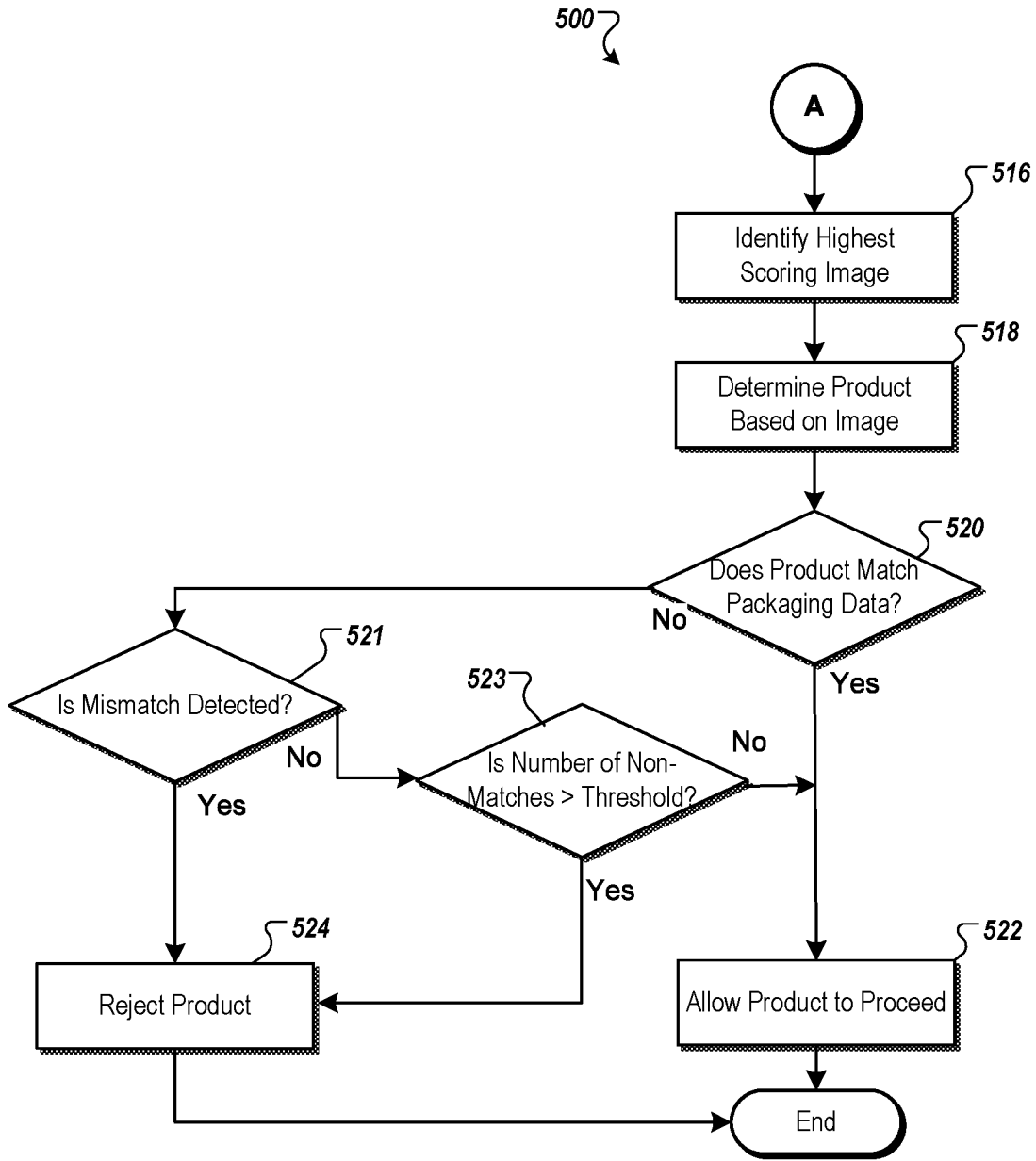


FIG. 5B

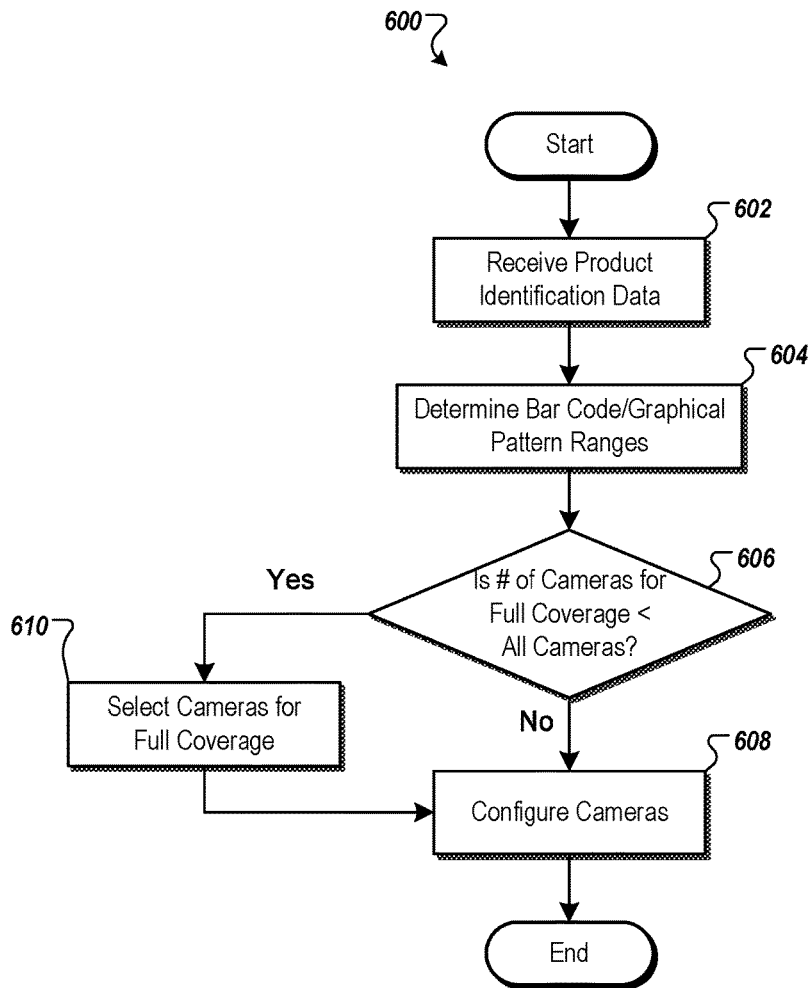


FIG. 6

SYSTEM AND METHOD FOR PERFORMING PRODUCTION LINE PRODUCT IDENTIFICATION

RELATED APPLICATIONS

This application incorporates by reference, in its entirety, the following prior patent: U.S. Pat. No. 9,147,326, entitled "Encoder Based Speed Compensated Reject System and Method," filed Jan. 28, 2013.

BACKGROUND

The present disclosure relates to a system and method for identifying products in a manufacturing production line.

Foods, medications, dietary supplements and other packaged products processed in a manufacturing facility are typically controlled to ensure consumer safety. The dangers in manufactured products include various forms of contamination and distribution of incorrect product. In some cases, when contamination of a product is identified, that particular product may have to be recalled and/or removed from production in order to ensure safety of those who consume the product. In addition, sometimes mismatched products that do not correspond to the product being processed on a production or packaging line may get mixed up with the product being processed or packaged, which can lead to errors in product deliveries to consumers.

In some cases, manufacturers can use computerized systems to identify the products on the production line based on an identification code such as a Universal Product Code (UPC). However, such computerized systems may rely on capturing a full UPC code or other identification markings in order to positively identify the product. In some instances where the products being processed on a manufacturing line have a uniform shape (e.g., rectangular) and orientation relative to a UPC detection device may be relatively uniform. However, a single manufacturing line in a production facility may process many types of products having a variety of packaging shapes that can result in various aspects and orientations of the packaging being presented to the UPC detection device, which can result in a partial UPC or no UPC being presented to the UPC detection device.

SUMMARY OF ILLUSTRATIVE EMBODIMENTS

The forgoing general description of the illustrative implementations and the following detailed description thereof are merely exemplary aspects of the teachings of this disclosure, and are not restrictive.

In certain embodiments, a system for identifying products on a production line includes a conveyor that transports containers of products along a production line that includes an inspection location including multiple cameras configured to obtain images of the containers at the inspection location from various positions and orientation angles. A controller receives the images captured by the cameras at the inspection location and detect features of a label on the packaging of the containers that can include at least a portion of a barcode, brand and product logos, ingredient lists, or nutrition information. If the full barcode is not visible in the images captured by the camera, the controller can identify the product associated with a given container based on the features that are visible in the images. In addition, the product can be identified based on the detected features in the images even if no portion of the barcode is present. The

controller calculates a quality score for the images obtained by each of the cameras and uses the image with the highest quality score to identify the product based on stored product pattern data. If the detected features match the pattern data for the product that is currently being processed on the production line, then the item is allowed to pass. If, however, the detected features do not match the pattern data, either due to a mismatch condition where an incorrect item is identified or a no match condition where neither the correct item nor an incorrect item are identified, then the controller may actuate a rejection device that diverts the item away from the production line. In some implementations, a predetermined number of items having a no match condition are allowed to pass on the production line before actuation of the rejection device.

Benefits of the system include being able to identify products on high volume production lines where the containers may be touching each other, causing portions or all of the barcode and label to be obscured from view of the cameras. In addition, containers having cylindrical or rounded shapes can still be identified by the system even if a portion or all of the barcode to be obscured from view of one or more of the cameras. Using a combination of features to identify the products improves the accuracy and speed of product detection and allows the products to be identified even if a barcode is not captured in the images by the cameras.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate one or more embodiments and, together with the description, explain these embodiments. The accompanying drawings have not necessarily been drawn to scale. Any values dimensions illustrated in the accompanying graphs and figures are for illustration purposes only and may or may not represent actual or preferred values or dimensions. Where applicable, some or all features may not be illustrated to assist in the description of underlying features. In the drawings:

FIG. 1 illustrates an exemplary product identification system;

FIG. 2 illustrates an exemplary block diagram of a programmable logic controller (PLC);

FIG. 3 illustrates an exemplary block diagram of types of data and processes executed by the PLC;

FIG. 4 illustrates an exemplary label for an item;

FIGS. 5A-5B illustrate an exemplary flow diagrams of a product identification process; and

FIG. 6 illustrates an exemplary flow diagram of a system configuration process.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The description set forth below in connection with the appended drawings is intended to be a description of various, illustrative embodiments of the disclosed subject matter. Specific features and functionalities are described in connection with each illustrative embodiment; however, it will be apparent to those skilled in the art that the disclosed embodiments may be practiced without each of those specific features and functionalities.

Reference throughout the specification to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with an

embodiment is included in at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases “in one embodiment” or “in an embodiment” in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics may be combined in any suitable manner in one or more embodiments. Further, it is intended that embodiments of the disclosed subject matter cover modifications and variations thereof.

It must be noted that, as used in the specification and the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context expressly dictates otherwise. That is, unless expressly specified otherwise, as used herein the words “a,” “an,” “the,” and the like carry the meaning of “one or more.” Additionally, it is to be understood that terms such as “left,” “right,” “top,” “bottom,” “front,” “rear,” “side,” “height,” “length,” “width,” “upper,” “lower,” “interior,” “exterior,” “inner,” “outer,” and the like that may be used herein merely describe points of reference and do not necessarily limit embodiments of the present disclosure to any particular orientation or configuration. Furthermore, terms such as “first,” “second,” “third,” etc., merely identify one of a number of portions, components, steps, operations, functions, and/or points of reference as disclosed herein, and likewise do not necessarily limit embodiments of the present disclosure to any particular configuration or orientation.

Furthermore, the terms “approximately,” “about,” “proximate,” “minor variation,” and similar terms generally refer to ranges that include the identified value within a margin of 20%, 10% or preferably 5% in certain embodiments, and any values therebetween.

All of the functionalities described in connection with one embodiment are intended to be applicable to the additional embodiments described below except where expressly stated or where the feature or function is incompatible with the additional embodiments. For example, where a given feature or function is expressly described in connection with one embodiment but not expressly mentioned in connection with an alternative embodiment, it should be understood that the inventors intend that that feature or function may be deployed, utilized or implemented in connection with the alternative embodiment unless the feature or function is incompatible with the alternative embodiment.

Aspects of the present disclosure are directed to identifying products on a manufacturing line that can be configured to process a wide variety of products for manufacturing and packaging. When items such as foods, medications, dietary supplements and similar products are manufactured and packaged, it may be necessary to inspect the products (or their packaging/container) to ensure that the correct product is packaged, shipped and, ultimately, used or consumed by the purchasers of the products. When an incorrect item is identified in the production or packaging process, it may be appropriate to reject the incorrect item by, for example, ejecting or diverting the item from the production line. In some implementations, cameras are configured on the manufacturing line to capture images of the products that are used to positively identify the products based on a detected barcode or other unique identification code.

Manufacturing production lines are very often configured to process a wide variety of products that come in a wide variety of shapes and sizes, which makes positively identifying the products based on a barcode alone more difficult because the high density of products on the production line along with the shape of product packaging may obscure some or all of the barcode from view. In the implementations

described further herein, the system can determine whether all of a barcode for a product is visible in a captured image of a product on the production line. If the full barcode is not visible then a captured image or if none of the barcode is present in the captured image, then the system can use a combination of features detected in images of the product to identify the product. Using a combination of barcode and feature detection to identify products on the production line improves accuracy rates of product identification and also improves overall processing efficiency since the system does not have to wait for an image of a full barcode to identify the product.

FIG. 1 illustrates a system **100** for identifying products according to certain embodiments of the present disclosure. The system **100** may be used to identify products (such as items **110**, for example) transported by conveyor **105** past at least one predetermined inspection location. In some implementations, the items **110** may be associated with a particular product that is being packaged for shipment to a customer on a manufacturing line. For example, inspection of products (or product packaging/containers) may take place in a manufacturing process as an in-line operation while, in other embodiments, inspection of products may take place during packaging or boxing of finished products. In some implementations, the items **110** may be identical packages of a type of food, drug, or other type of product. Although only five items **110** are illustrated in FIG. 1, it can be understood that a typical production line processes a continuous stream of items like those illustrated as items **110**. The system **100** may be configured to identify the items **110** to ensure that the correct products have been processed and packaged for a customer. In some implementations, the items **110** may be packaged in boxes, jars, tubes, tubs, or any type of container that can have a variety of shapes and sizes. As illustrated in FIG. 1, conveyor **105** transports the items **110** from left to right.

At the inspection location (the approximate position of item **110C**), the system **100** may include one or more cameras **115** positioned to capture images or video of the items as they pass the predetermined inspection location on conveyor **105**. Although three cameras are shown in FIG. 1, some implementations may include additional cameras, while other embodiments may only have one or two cameras. The number of cameras, in some examples, may be determined based on one or more of a number of sides of the product packaging, number of sides of the product packaging including identifying information, size of the product, density of the product on the conveyor **105** (e.g., if more than 1 item may be side-by-side), etc. For example, some product items may not have useful identification information on a top surface, so camera **115C** may not be used to identify such items.

In some implementations, the number of cameras **115** included in the system **100** may be based on feature capture angle ranges of each of the cameras **115** for the items **110** that are processed by the system **100**. In addition, the system **100** can activate and/or deactivate one or more cameras **115** of the system **100** based on the feature capture angle ranges. The feature capture angle ranges may correspond to a range of rotational degrees that each camera is able to capture a feature for a particular item **110**, which can be based on characteristics of the cameras **115** (e.g., camera orientation/aspect angle, distance of camera from the item, etc.) as well as dimensions of the packaging of the items **110** and features of a label on an outer surface that is used to identify the items **110**.

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For example, the items **110** can include a cylindrically shaped package such as a soup can, condiment jar, yogurt container, or single serving cereal bowl that may have a label affixed to one or more outer surfaces of the items **110** that distinguish the items **110** from other products. In one implementation, the label is made of a flexible material (e.g., paper, flexible plastic) that is wrapped around an outer rounded surface of the items **110**. In other implementations, the label may be printed or stamped on the outer surface of the items **110**. The label for the items **110** may include a number of identifying features that can be used by the system **100** to distinguish the items **110** from other products. The identifying features can include a barcode **140**, matrix or 2D barcode, QR code, or any type of identification code that distinguishes the item **110** from other types of products such as a universal product code (UPC), brand and/or product logos, ingredient lists, nutrition information, quantity information, and any other information included on the label. In circumstances involving cylindrical or rounded shape packaging causing partial obscuring of an affixed label, the cameras **115** may be able to capture a particular feature on the label for a predetermined number of degrees of rotation of the item **110**.

In some implementations, the number of cameras **115** that are used to identify the items is based on how many degrees of rotation a particular camera **115** is able to capture a full or complete barcode **140** on the label. As the items **110** are transported by the conveyor **105**, a rotational orientation of the items **110** with respect to each of the cameras **115** may be (or become) essentially random due to a randomized nature of how the items **110** are placed on the conveyor, contact between the items **110** on the conveyor **105** that causes rotational shifting of the items **110**, and the like. For example, items **110A-110C** are shown in a variety of different rotational orientations with respect to the cameras **115**. In some embodiments, such as those exemplified in FIG. 1, the spacing of items on conveyor **105** may be minimized to achieve a high production throughput. In some embodiments, the production throughput, for example, may exceed 500 items per minute (<120 ms per item). In some embodiments, the items on conveyor **105** may be touching or in very close proximity to one another. Under such conditions, the barcodes **140** on some items **110** (such as item **110C**, for example) may be hidden from view of the any of the cameras **115**. For example, only a part of barcode **145** on item **110C** may be visible to any of the cameras **115**.

In one example where the system **100** includes four cameras **115**, each camera may capture the full barcode **140** for the each of the items **110** over 70 degrees of rotation of the individual item **110**. Therefore, the cameras **115** can be positioned to capture the full barcode of the items **110** over 280 degrees of rotation of the item **110**, and the captured barcode **140** can be used by the system **100** to identify the item **110**. For the remaining 80 degrees of rotation, the cameras **115** can capture a partial barcode and/or other features of the label affixed to the packaging of the item **110**, which can be used by the system **110** to identify the item **110**. Because the types of items **110** processed by the system **100** have packaging shapes and sizes, label features, and barcodes, each type of item **110** may have different ranges over which the barcode **140** and other features may be captured. For example, another type of product, such as a yogurt container, may have a barcode that is rotated 90 degrees from the barcode **140** shown on the items **110** in FIG. 1. The rotated barcode may result in a greater range of orientation angles over which a full barcode may be captured by the cameras **115**, which can result in a lower

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number of cameras being used by the system **100** to capture images used to identify the items **110**. In addition, other design characteristics of the labels of the items **110** may affect the number of cameras **115** that are used to identify the product. For example, the graphical features of a single serving cereal bowl label may be more easily identified in the captured images than the graphical features of a soup can label, which can result in only two cameras **115** being configured to capture images when single serving cereal bowls are being processed by the system **100** while a greater number of cameras **115** may be used to capture images of the soup cans.

In some implementations, the system **100** can adaptively configure the number of cameras **115** that are activated to capture images of the items **110** based on characteristics of the labels affixed to the items **110** being transported by the conveyor **105**. By adaptively determining the number of cameras that are used by the system **100**, power savings can be achieved by powering down the cameras **115** that are not in use or putting the cameras **115** that are not in use into a sleep mode. In addition, using fewer cameras **115** to acquire images of the items **110** reduces a processing load on the PLC **120** or other processors associated with the system **100**, which can cause a greater number of items to be processed by the system **100** in a shorter period of time. Because of the high production throughput (>500 items per minute) through the system **100**, in some embodiments, the process of identifying a product may be required to be completed in less than, for example, 120 ms. Therefore, reducing the number of acquired images for processing can result in improved processing times. In addition, the system **100** can automatically control an orientation angle and position of the cameras **115** based on the number of cameras **115** being used. The use of the term "camera" herein is not intended to be limiting. Any type of area or line scan image capture device, including still cameras, video cameras, line scan cameras and the like may be used as an application demands.

In some implementations, the system logs a timestamp of item information capture. The system **100** may determine, for example, that an item **110** has reached the inspection location based on a speed of conveyor **105** and a time at which the item **110** is detected by sensor **150**.

The images captured by cameras **115** may be fed into programmable logic controller (PLC) **120** that executes one or more software processes associated with the system **100** and outputs control signals to other controllers and electronically-activated components of the system **100**. One example of a suitable PLC for the system **100** is an Allen Bradley PLC. As an illustrative example, FIG. 2 provides a simplified hardware block diagram of a PLC **200**, which can be implemented as the PLC **120** in the system **100**. The description of the PLC **200** is not meant to be limiting, and can include other components than those described herein. The PLC **200** may include a central processing unit (CPU) **206** that executes one or more software processes associated with the system **100**. Software instructions for the processes can be stored in memory **202**. The memory **202** can include both volatile and non-volatile memory and can store various types of data associated with executing the processes related to capturing images of items **110** on the conveyor and identifying the product based on the captured images. The PLC **200** includes an input interface **204** for connecting to various devices that provide inputs to the PLC **200** such as the cameras **115**, conveyor **105**, rejection conveyor **145**, conveyor controller **135**, sensor **150**, rejection device **130**, and any other device associated with the system **100**. The PLC **200** also includes an output interface for connecting

and providing control signals to any device controlled by the PLC 200 including the cameras 115, rejection conveyor 145, conveyor controller 135, rejection device 130, and any other device controlled by the PLC 200. The PLC 200 also includes a power supply 210 as well as a communication device 212 that allows the PLC 200 a wired or wireless communication interface between the PLC 200 and any other device of the system 100 or other systems.

Referring back to FIG. 1, in some implementations, the PLC 120 can output data and control signals to conveyor controller 125, which controls operation of conveyor 105 and rejection line conveyor 145, which can include starting and/or stopping conveyors 105 or 145 or adjusting the speed or direction of the conveyors 105 or 145. The functions and operations performed by the conveyor controller 135 can also be integrated into functions performed by the PLC 120.

The PLC 120 may also control the acquisition of images by cameras 115 by, for example, controlling a precise time for image capture. The PLC 120 may also control other parameters of cameras 115 such as focus, aperture, white balance, exposure/shutter speed, etc. The PLC 120 can also power down (or put into sleep mode) any cameras that are not being used to capture images of a particular item 110 or activate and configure for use any additional cameras. In some embodiments, sensor 150 may provide an advance indication for a times at which a product will reach the inspection location. In other embodiments, cameras 115 may capture a continuous sequence of images (a video sequence, for example), and the PLC 120 may select the most appropriate image for each item as it passes the inspection location. In some embodiments, sensor 150 may be an optical sensor that may employ a light emitter and photo sensor that detects the presence of an item on the conveyor 105. In other embodiments, sensor 150 may be an ultrasonic sensor that may employ an ultrasonic emitter and ultrasonic sensor that detects the presence of an item on the conveyor 105. In yet other embodiments, sensor 150 may employ two devices (a light emitter and photo sensor, for example), one on either side of conveyor 105, to sense the passing of an item. In another embodiment, the products on conveyor 105 may include radio frequency identification (RFID) tags. In such an embodiment, sensor 150 may include RFID detection circuitry.

In some implementations, the PLC 120 configures one or more of the cameras to acquire images of the items 110 based on the type of product being processed by the system 100. For example, the PLC 120 can store various types of data in memory that can be used to determine how to configure the cameras 115 to acquire images of a particular product. The data that is used to determine the number, position, and orientation of the cameras 115 of the system can be determined based on stored packaging pattern data that can include label templates for various types of products processed by the system 100, product identification data that includes unique identification codes for each of the items that may correspond to the UPC or another type of unique identifier, production schedule data that includes times that various types of products are scheduled to be processed by the system 100, and camera configuration data that indicates a current status of each of the cameras 115 with respect to position, orientation angle, and the like.

The PLC 120 may process images from cameras 115 to identify indicia or unique features on each item 110 that correspond to the packaging pattern data to positively identify the item 110 whose image is captured by the cameras 115 and determine whether the item 110 corresponds to a type of item currently being processed. In some implemen-

tations, the PLC 120 determines a quality score for each of the images captured by the cameras 115. The quality score provides an indication of how well the features in a captured image can be used to positively identify the item 110. The quality score may correspond to a value in any range of values, such as 0 to 10, 0 to 100, 0 to 1000, or any other range.

In some implementations, if a calculated quality score is greater than a predetermined threshold, then the PLC 120 may determine that a captured image corresponds to a particular product. In addition, images having quality scores less than a second predetermined threshold may be considered as having too few features to be able to accurately recognize a type of product and thus any image having a quality score less than the second predetermined threshold is discarded. The PLC 120 may also identify the item 110 based on a relative quality score that provides an indication of how well the captured image represents a particular product versus any other product that is processed by the system 100. For example, an item 110 with a low relative quality score can indicate that the features detected in the image indicate correspondence to two or more different products within a predetermined range of similarity. On the other hand, an item having a high relative quality score can indicate that the features detected in the image are strongly associated with one product as opposed to any other product processed by the system 100.

In addition, the quality score for each image may be represented by either a percentage or raw score. As a percentage, the quality score indicates what percentage of the image includes detectable features of the item 110 that can be used to distinguish the item 110 from other products that are processed by the system 100. In other examples, the percentage quality score indicates a percentage of the container for the item 110 that has been captured by the image. For example, an image where an entire container of the item 110 is captured may have a higher percentage quality score than an image where only a portion of the container is captured. In implementations where the quality score is represented by a raw score, the score may represent a number of detectable features of the item 110 that can be used to distinguish the item 110 from other products that are processed by the system 100.

In some examples, if a full barcode 140 is captured in an image, that particular image receives a highest possible quality score in the given range. In examples where the captured images include a partial barcode or no barcode, the quality score may be calculated to indicate a number or percentage of features that are detected in the image that can be used to identify the item 110. For example, the detected features can include full or partial product or company logos, nutrition information, ingredient list, quantity information, or any other image features. In some implementations, the product can be positively identified based on the detected features even if no barcode is present in the image. Once the quality scores have been determined for all of the captured images of an item 110, the PLC 120 selects the image with the highest quality score to be compared to packaging patterns of products stored in memory of the PLC 120. The PLC 120 may use any type of image processing and/or pattern recognition algorithm that is known to compare the image with the highest quality score to the stored packaging patterns. For example, the PLC 120 can use edge detection, background subtraction, or frame differencing algorithms to locate the items 110 within the image. Because the cameras 115 capture images of the items 110 in a relatively static environment with consistent lighting, less

robust object detection can be used to locate the items **110** within the image. For example, frame differencing provides highly accurate object detection results in a relatively static environment with low processing time. Meanwhile, template matching object detection algorithms provide highly accurate results but also may have high processing times. In some examples, the processing time for template matching can be reduced by identifying selected features/indicia of a pattern template for a product that distinguish a given product from other products processed by the system and comparing the selected features to detected features in the images captured by the cameras **115**. In some implementations, the selected features can include particular color patterns at various locations in the image, detection of various shape patterns in the images, and alignment of the various components of an item label within an image. The templates that are compared to the items **110** detected in the images may be represented by eigenvectors that can be compared to vector representations of the item features or portions of item features detected in the images. If the identified product for the item **110** matches the product that is currently being processed by the system **100**, resulting in a match condition, then the item **110** is allowed to continue on the conveyor **105**. If, however, a match condition does not occur for an item **110**, then the item may be diverted onto rejection conveyor **145** by rejection device **130**.

In some examples, when a match condition does not occur, then the item **110** may have been matched to another product that does not correspond to the product currently being processed by the system, resulting in a mismatch condition. In some aspects, if a mismatch condition is detected, then the mismatched item is diverted onto the rejection conveyor **145** by the rejection device **130**, and a lockout of the system **100** may occur in which the conveyor **105** is shut down until a lockout clearing process is performed. In some implementations, the lockout clearing process may include authentication of an authorized user with a RFID key and/or password who clears the lockout and restarts the system **100** after investigation into the cause of the mismatch condition. In other examples, if a match condition does not occur, then the item **110** may not have been matched to the correct product nor an incorrect product, resulting in a no match condition. The no match condition may occur in situations where the images captured by the cameras **115** do not include enough detectable features to positively identify the item **110**. The no match condition may also occur when one or more of the cameras **115** may have malfunctioned or failed. In some examples, a predetermined number of items **110** may be allowed to pass on the conveyor **105** before the non-matched item is diverted onto the rejection conveyor **145** by the rejection device **130** and/or the system lockout occurs.

The system **100** may also include a rejection device **130** and corresponding rejection conveyor **145** that may be configured to eject or divert a specific item from conveyor **105** under the control of controller **125**. In some implementations, if the PLC **120** determines that the item **110E** identified on the conveyor **105** does not correspond to the type of item currently being processed, the PLC **120** can issue a control signal to the rejection device **130** to divert the item **110E** onto the rejection conveyor **145** and away from the path provided by the conveyor **105**. The rejection device **130** can be any type of device that can either directly make contact or cause another object to make contact with the item **110E** in order to cause the item **110E** to move off the conveyor **105** and onto the rejection conveyor **145**. In some implementations, the rejection device **130** may be an arm,

blade, pusher, stepper motor, servo motor, air cylinder, pneumatic blow-off, or other device. The type of rejection device **130** that is used to divert the item **110E** off the conveyor **105** may be based on a type of packaging of the item **110E**. For example, gentler rejection devices such as the stepper motor, servo motor, or pusher may be used to divert breakable or deformable items that may be packaged in glass or another type of breakable or highly malleable material. Similarly, lighter items that are unbreakable may be blown off the conveyor **105** and onto the rejection conveyor **145** with the air cylinder or pneumatic blow-off. In some implementations, the PLC **120** can also activate an alarm or other type of alert mechanism when an item is diverted onto the rejection conveyor **145** in response to a detection of a product mismatch or no match condition. The alarm can include any type of audio or visual indication that alerts a user that a product mismatch or no match condition was detected, and the corresponding item was diverted off the conveyor **105** and onto the rejection conveyor **145**. Examples of alarms include any combination of an audible tone or spoken alarming condition message, a blinking light or other type of visual indication, and a product message output report to a computer log or messaging system that can provide text messages, emails, or other types of messages to system users indicating that a product mismatch or no match condition was detected. In some examples, when a predetermined number of product mismatches or no matches are detected within a predetermined period of time, the PLC **120** may shutdown the conveyor **105** until a user verifies that the correct products are being processed by the system **100** and resets the PLC **120** to clear the alarming condition.

The system **100** illustrated in FIG. **1** provides a simplified arrangement of a product inspection system according to some embodiments of the present disclosure for the sake of clarity. Other components that may be useful for some embodiments described in the present disclosure are not illustrated in FIG. **1**. These include, but are not limited to, lighting, support structures, conveyor drive, camera control equipment, etc. For example, to capture appropriate images of the bar code **140** or other identifying indicia, the lighting may be adjusted to avoid glare/reflection/oversaturation of the image, etc.

Turning to FIG. **3**, an alternative data processing and storage configuration for the system **100** is presented. In some implementations, the software processes associated with the system **100** can be executed by processing resources such as servers, database servers, or any other type of processing resources including cloud-based computing resources. For example, processing system **300** is associated with and connected to the system **100** and can include one or more engines or modules that perform processes associated with identifying products transported by the conveyor **105** of the system **100**. In some implementations, the processing system **300** can connect to the system **100** via a wired or wireless connection. References to the engines or modules throughout the disclosure are meant to refer to software processes executed by circuitry of one or more processing circuits, which can also be referred to interchangeably as processing circuitry. The processes executed by the processing system **300** correspond to processes that may be executed by the PLC **120** of the system **100** described above in FIG. **1**.

For example, the processing system **300** includes a camera configuration engine **302** that configures the cameras **115** of the system **100** based on the type of product being processed by the system **100**. In some implementations, the camera configuration engine **302** can adaptively configure

the number of cameras **115** that are activated to capture images of the items **110** based on characteristics of the labels affixed to the items **110** being transported by the conveyor **105**. For example, the camera configuration engine **302** can activate and/or deactivate one or more cameras **115** of the system **100** based on the feature capture angle ranges. The feature capture angle ranges may correspond to a range of rotational degrees that each camera is able to capture a feature for a particular item **110**, which can be based on characteristics of the cameras **115** (e.g., camera orientation/aspect angle, distance of camera from the item, etc.) as well as dimensions of the packaging of the items **110** and features of a label on an outer surface that is used to identify the items **110**. In one example where the system **100** includes four cameras **115**, each camera may capture the full barcode **140** for the each of the items **110** over 70 degrees of rotation of the individual item **110**. Therefore, the cameras **115** can be positioned to capture the full barcode of the items **110** over 280 degrees of rotation of the item **110**, and the captured barcode **140** can be used by the system **100** to identify the item **110**. For the remaining 80 degrees of rotation, the cameras **115** can capture a partial barcode and/or other features of the label affixed to the packaging of the item **110**, which can be used by the system **110** to identify the item **110** even when some or none of the barcode is present in the captured images. The camera configuration engine **302** may also control other parameters of cameras **115** such as focus, aperture, white balance, exposure/shutter speed, etc. The camera configuration engine **302** can also power down (or put into sleep mode) any cameras that are not being used to capture images of a particular item **110**.

The processing system **300** also includes an image acquisition engine **304** that acquires the images captured by the cameras **115**. In some implementations, the image acquisition engine **304** outputs a control signal to the cameras **115** to capture one or more images of the items **110** based on sensor data received from sensor **150** indicating a position of the items **110** on the conveyor **105**. The image acquisition engine **304** receives the images from each of the cameras **115** and annotates captured image data **322** for each of the images with the particular camera **115** that captured the image along with configuration parameters for that particular camera **115**.

The processing system **300** also includes an image processing engine **306** that detects features of the images that can be used to identify the type of product being transported on the conveyor **105**. In some implementations, the features can include any identifying marks that are visible on an outer surface of the products and may include a barcode, brand and/or product logos, ingredient lists, nutrition information, quantity information, and any other information included on the label. The image processing engine **306** can use any image processing algorithms that are known to detect the features of the images. The features can include patterns, colors, sizes, shapes, and locations of various objects that are detected on the label of the product.

The processing system **300** also includes a score determination engine **308** that calculates a quality score for each of the captured images. The quality score provides an indication of how well the features in a captured image can be used to positively identify the item **110**. The quality score may correspond to a value in any range of values, such as 0 to 10, 0 to 100, 0 to 1000, or any other range. In some examples, if a full barcode **140** is captured in an image, that particular image receives a highest possible score in the range. In examples where the captured images include a partial barcode or no barcode, the quality score may be

calculated to indicate a number or percentage of features that are detected in the image that can be used to identify the item **110**. For example, the detected features can include full or partial product or company logos, nutrition information, ingredient list, quantity information, or any other image features. Once the quality scores have been determined for all of the captured images of an item **110**, the score determination engine **308** selects the image with the highest quality score to be compared to packaging pattern data **314** stored in data repository **322**.

The processing system **300** also includes a product comparison engine **312** that compares the image with the highest quality score to the packaging pattern data **314** for all possible products that are manufactured on a production line or at a manufacturing facility. The product comparison engine **312** may use any type of image processing and/or pattern recognition algorithm that is known to compare the image with the highest quality score to the packaging pattern data **314**. In some implementations, key feature points are identified in the captured image, which are compared to key feature points in the stored packaging patterns. If the identified product for the item **110** matches the product that is currently being processed by the system **100**, then the item **110** is allowed to continue on the conveyor **105**. Degree of certainty in match, for example, may be required to be at least 95%, 99%, or 100%. If, however, the identified product does not correspond to the product currently being processed by the system **100**, then the item is diverted onto rejection conveyor **145** by rejection device **130**. For example, if degree of certainty in match is less than a threshold amount, such as less than 95% certainty, the item may be rejected or classified as a non-match to a particular product. Conversely, if the system generates a positive match (e.g., meeting or exceeding a threshold of certainty) for a different product than the anticipated product, corresponding to a mismatch condition, the system **100** may divert the item onto the rejection conveyor **145**.

The processing system **300** also includes a rejection engine **312** that controls the diversion of rejected items onto the rejection conveyor **145** in response to detection of a product mismatch condition or no match condition by the product comparison engine **310**. The system **100** may also include a rejection device **130** and corresponding rejection conveyor **145** that may be configured to eject or divert a specific item from conveyor **105** under the control of controller **125**. In some implementations, if the product comparison engine **310** determines that an item identified on the conveyor **105** does not correspond to the type of item currently being processed, the rejection engine **312** can issue a control signal to the rejection device **130** to divert the item onto the rejection conveyor **145** and away from the path provided by the conveyor **105**. The rejection device **130** can be any type of device that can either directly make contact or cause another object to make contact with the rejected item in order to cause the item to move off the conveyor **105** and onto the rejection conveyor **145**. In some implementations, the rejection device **130** may be an arm, blade, pusher, stepper motor, servo motor, air cylinder, pneumatic blow-off, or other device. In some implementations, the rejection engine **312** can also activate an alarm or other type of alert mechanism when an item is diverted onto the rejection conveyor **145** in response to a detection of a product mismatch or no match condition.

Further, in some embodiments, the rejection engine **312** may confirm redirection of the product onto the rejection

conveyor 145. An additional sensor, for example, may identify that a new item has been added to the rejection conveyor 145.

In some implementations, the processing system 300 is connected to data repository 322 via a wired or wireless connection. The data repository 322 can be configured to store data that is used by the processing engines of the processing system 300 or produced by the processing system 300 during execution of the processes. For example, the data repository 322 can include packaging pattern data 314 that can include label templates for various types of products processed by the system 100, product identification data 316 that includes unique identification codes for each of the items that may correspond to the UPC or another type of unique identifier, production schedule data 318 that includes times that various types of products are scheduled to be processed by the system 100, and camera configuration data 320 that indicates a current status of each of the cameras 115 with respect to position, orientation angle, and the like. The data repository 322 can also include captured image data 322 that can be used as historical data to further refine the packaging pattern data 314 for the products processed by the system 100.

Turning to FIG. 4, an exemplary label 400 for an item is illustrated. In implementations where the item has a rounded or cylindrical shape, the label 400 may be made of a flexible material (e.g., paper, flexible plastic) that is wrapped around an outer rounded surface of the item. In other implementations, the label 400 may be printed or stamped on the outer surface of the item. The label 400 for the item may include a number of identifying features that can be used by the system 100 to distinguish the item from other products. For example, the features can include a brand logo 402, product logo 404, product picture 406, nutrition information 408, ingredients 410, and barcode 412. In some implementations, the system 100 can identify the item based on the detected features as well as the locations of the features relative to other features on the label 400. Additional features other than those shown in FIG. 4 can also be included on the label 400, which may also be used to identify the product, such as inspection stickers, quantity information, cooking directions, etc.

FIGS. 5A and 5B are flow diagrams that schematically illustrate a method 500 of product identification, and processing of the results of the identification, according to some embodiments of the present disclosure. The descriptions for the flow diagrams illustrate a particular ordering of processes, steps, and decision points, but it can be understood that the steps of the processes can be performed in a different order. Additionally, certain steps of the flow diagrams, in other embodiments, may be performed in parallel.

In some implementations, the method 500 begins with configuring a system, such as the system 100 of FIG. 1, for processing a particular product (502). Turning to FIG. 6, a flow diagram of a method 600 for configuring a system is illustrated. Turning to FIG. 6, in some implementations, the method 600 begins with receiving identification data for the product (602) from a sensor (e.g., 150), one or more of cameras (e.g., cameras 115), or a user input indicating that items of the product are being transported by a conveyor (e.g., 105). The identification data can include a UPC or other unique identification code or machine readable indicia, product name, or any other information that can be used to identify the product. In some embodiments, the system 100 can use stored production schedule data to determine the type of product to be transported on the conveyor 105.

In response to receiving the product identification data for the product, in some implementations, a number of cameras to activate is determined based on feature capture angle ranges for the product (604). The feature capture angle ranges may correspond to a range of rotational degrees that each camera is able to capture a feature for a particular item, which can be based on characteristics of the cameras (e.g., camera orientation/aspect angle, distance of camera from the item, etc.) as well as dimensions of the packaging of the items and features of a label on an outer surface that is used to identify the items.

If the number of cameras to activate to obtain full coverage of the label on the items by the cameras is less than the total number of cameras connected to the system (608), in some implementations, the cameras to be configured to capture images of the items are selected (610). For example, the PLC 120 of FIG. 1 may select the cameras. The selection, for example, can be based on an orientation of the cameras with respect to one another as well as the characteristics of the packaging and label of the items. The selected cameras may be configured, for example, by outputting control signals to turn on or wake the cameras from a sleep mode if necessary and to modify an orientation angle and/or position of the cameras so that the cameras can capture images that allow for positive identification of the items by the captured images.

Referring back to FIG. 5A, in response to the system being configured for product processing, in some implementations, each of the cameras captures at least one image of an item as the items pass a predetermined inspection location on a conveyor (504). The PLC 120 of FIG. 1, for example, may determine that an item 110 has reached the inspection location based on a speed of conveyor 105 and a time at which the item 110 was detected by the sensor 150.

For each captured image, in some implementations, it is determined whether a full barcode is visible in the image (506). The PLC 120 of FIG. 1, for example, may determine whether the complete barcode is captured within an image. If the full barcode is visible in the image, in some implementations, the barcode is extracted from the image (510). However, if the full barcode is not visible in the image, in some implementations, an image feature pattern is extracted from the image (508). In some embodiments, the image feature pattern includes partial or no barcode as well as partial or full product or company logos, nutrition information, ingredient list, quantity information, color, product shape, information region alignment, or any other image features.

In some implementations, an image quality score is determined based on the detected barcode or image feature pattern (512). For example, the PLC 120 of FIG. 1 may determine a quality score for each of the images captured by the cameras 115. The quality score provides an indication of how well the features in a captured image can be used to positively identify the item 110. The quality score may correspond to a value in any range of values, such as 0 to 10, 0 to 100, 0 to 1000, or any other range. In some examples, if a full barcode 140 is captured in an image, that particular image receives a highest possible score in the range. In examples where the captured images include a partial barcode or no barcode, the quality score may be calculated to indicate a number or percentage of features that are detected in the image that can be used to identify the item 110. For example, the detected features can include full or partial product or company logos, nutrition information, ingredient list, quantity information, or any other image features.

In some implementations, images of an item are processed until all of the images captured by each of the cameras have been processed (514). For example, the PLC 120 of FIG. 1 may continue to process images obtained by each of the cameras and determine quality scores of each image. In some embodiments, a number of images are processed simultaneously in parallel, which reduces a total processing time. In some embodiments, if a quality score matching a particular threshold is reached (e.g., 98/100, 995/1000, etc.) the high quality image may be selected and the remaining images discarded from further processing. For example, to reduce processing cycles and increase speed, upon obtaining an image determined capable of producing a match, the system may cease processing remaining images captured by the cameras.

In some implementations, processing of images may be done on a camera-by-camera (or camera angle by camera angle) basis starting with a camera most likely to capture a positive match. For example, angles capturing sides of packages rather than an upper view of packages may be considered more likely to produce matching product data.

Turning to FIG. 5B, once the quality scores have been determined for all of the captured images of an item (or, conversely, one image or a threshold number of images deemed containing a threshold quality of image are identified), in some implementations, the image with the highest quality score may be identified and selected for comparison to packaging patterns of known products (516). For example, the PLC 120 of FIG. 1 may identify and select one or more images for comparing to packaging patterns stored in memory of the PLC 120.

In some implementations, image processing and/or pattern recognition algorithm(s) are applied to compare the image(s) with the highest quality score(s) to the stored packaging patterns (518). The PLC 120 of FIG. 1, for example, may compare one or more images to stored packaging patterns for all types of products that are processed by the system 100 or in the same manufacturing facility as the system 100. In other embodiments, only packaging patterns associated with the anticipated item are used to identify or discard the item. Because a probability of detecting a product mismatch may be less than a probability of detecting the correct item on the conveyor 105, the PLC 120 may prioritize comparing the highest scoring image to the packaging pattern for the product being processed by the system 100 so that a match is detected before comparisons are performed with packaging patterns for other products. In some embodiments, key feature points are identified in the captured image, which are compared to key feature points in the stored packaging patterns. In some implementations, a match condition is detected when a number or percentage of key feature points detected in the image that correspond to key feature points of a stored product pattern for the product being processed by system 100 is greater than a predetermined threshold, otherwise, a mismatch condition or a no match condition is detected. If, however, the number or percentage of key feature points that correspond between the captured image and a stored product pattern is less than the threshold but greater than the number or percentage of corresponding feature points for any of the other stored product patterns by more than a predetermined amount, the PLC 120 may still detect a match condition.

If the identified product for the item matches the product that is currently being processed by the system (520), in some embodiments, the item is allowed to continue on the conveyor (522). For example, the PLC 120 of FIG. 1 may determine that a particular item 110 may continue on the

conveyor 105. If, however, the identified product does not correspond to the product currently being processed by the system, then in some examples, it is determined whether a mismatch condition or a no match condition exists.

A mismatch condition occurs when the item is positively identified as another product which is different from the product which is currently being processed by the system (521). If, in some aspects, the mismatch condition has occurred, then the item is diverted onto a rejection conveyor by a rejection device (524). For example, the conveyor controller 135 of FIG. 1 may divert the particular item 110 onto the rejection conveyor 145. In the event a mismatch condition is detected the PLC may halt the production line and prevent restarting of the production line until a user logs in (authenticates to) the PLC and clears the lockout code.

A no match condition occurs when the container cannot be positively identified. This occurs, for example, when a product label cannot be properly read or when the product label can be read but does not match any product in the PLC memory. In some examples, in the event of a no match condition the conveyor controller 135 of FIG. 1 may divert the particular item 110 onto the rejection conveyor 145. The PLC 120 may keep a running count of "no match" events and when the number of detected no match conditions is greater than a predetermined threshold (523) then the item production line may be halted as described above. However, if the number of detected no match conditions is less than the predetermined threshold, then the PLC 120 of FIG. 1 may simply reject the particular item and allow the production line to continue operating.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the present disclosures. Indeed, the novel methods, apparatuses and systems described herein can be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods, apparatuses and systems described herein can be made without departing from the spirit of the present disclosures. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the present disclosures.

What is claimed is:

1. A system comprising:

a plurality of image capturing devices configured to acquire images of containers moving along a production line at an inspection location on the production line;

a rejection device; and

a controller communicatively coupled to the plurality of image capturing devices and the rejection device, wherein the controller is programmed to configure the plurality of image capturing devices for image acquisition based on properties of the containers moving along the production line,

identify a product associated with each of the containers moving along the production line based on at least one of a portion of a product identification code and a portion of additional features detected in the images, wherein

identifying the product associated with each of the containers moving along the production line comprises comparing an image having a highest quality score of the images acquired by each of the plurality of image capturing devices to one or more packaging patterns stored in memory of the

controller, the packaging patterns associated with types of containers processed on the production line,

determine whether a container is associated with a match condition in response to identifying the product associated with the container, the match condition reflecting that the container is associated with predetermined properties or characteristics, in response to a match condition, determine a pass result, and otherwise determine a non-pass result, and

in response to determining the non-pass result, output a signal to actuate the rejection device that removes the container from the production line.

2. The system of claim 1, wherein the containers have a cylindrical shape.

3. The system of claim 1, wherein the controller is further programmed, in response to detecting a full identification code in one of the images, to identify the product associated with a container based on the full identification code.

4. The system of claim 1, wherein the controller is further programmed to determine a quality score for each of the images acquired by the plurality of image capturing devices, the quality score providing an indication of a quantity of the at least one of the portion of the product identification code and the portion of the additional features detected in the images.

5. The system of claim 1, wherein the packaging patterns include templates for labels associated with the types of containers processed on the production line including at least one of the product identification code, brand logos, product logos, ingredient lists, nutrition information, and container quantity information.

6. The system of claim 1, wherein each of the plurality of image capturing devices is configured to acquire the images of the containers from a different orientation angle.

7. The system of claim 1, wherein configuring the plurality of image capturing devices for image acquisition further includes determining a number of activated image capturing devices for acquiring the images of the containers based on at least one of a packaging shape and label characteristics of the containers.

8. The system of claim 7, wherein configuring the plurality of image capturing devices includes activating one or more selected image capturing devices and deactivating one or more unselected image capturing devices.

9. The system of claim 8, wherein configuring the plurality of image capturing devices further includes adjusting at least one of an orientation angle and position of the image capturing devices based on at least one of the image packaging shape and label characteristics of the containers.

10. A method, comprising:

acquiring, with a plurality of image capturing devices, images of containers moving along a production line at an inspection location on the production line;

configuring, with a controller, the plurality of image capturing devices for image acquisition based on properties of the containers moving along the production line;

identifying, with the controller, a product associated with each of the containers moving along the production line

based on at least one of a portion of a product identification code and a portion of additional features detected in the images, wherein

identifying the product associated with each of the containers moving along the production line comprises comparing an image having a highest quality score of the images acquired by each of the plurality of image capturing devices to one or more packaging patterns stored in memory of the controller, the packaging patterns associated with types of containers processed on the production line;

determining, with the controller, whether a container is associated with a match condition in response to identifying the product associated with the container, the match condition reflecting that the container is associated with predetermined properties or characteristics; in response to a match condition, determining a pass result with the controller, and otherwise determining a non-pass result with the controller; and

in response to determining the non-pass result, actuating a rejection device with the controller that removes the container from the production line.

11. The method of claim 10, wherein the containers have a cylindrical shape.

12. The method of claim 10, further comprising:

in response to detecting a full identification code in one of the images, identifying, with the controller, the product associated with a container based on the full identification code.

13. The method of claim 10, further comprising:

determining, with the controller, a quality score for each of the images acquired by the plurality of image capturing devices, the quality score providing an indication of a quantity of the at least one of the portion of the product identification code and the portion of the additional features detected in the images.

14. The method of claim 10, wherein the packaging patterns include templates for labels associated with the types of containers processed on the production line including at least one of the product identification code, brand logos, product logos, ingredient lists, nutrition information, and container quantity information.

15. The method of claim 10, wherein each of the plurality of image capturing devices is configured to acquire the images of the containers from a different orientation angle.

16. The method of claim 10, wherein configuring the plurality of image capturing devices for image acquisition further includes determining a number of activated image capturing devices for acquiring the images of the containers based on at least one of a packaging shape and label characteristics of the containers.

17. The method of claim 16, wherein configuring the plurality of image capturing devices includes activating one or more selected image capturing devices and deactivating one or more unselected image capturing devices.

18. The system of claim 17, wherein configuring the plurality of image capturing devices further includes adjusting at least one of an orientation angle and position of the image capturing devices based on at least one of the image packaging shape and label characteristics of the containers.